Space Technology Research Grants

Extending Controllable Adhesive Technologies to Irregular Surfaces with Soft Robotic Actuation

Completed Technology Project (2017 - 2021)

Project Introduction

Using the compliant materials and distributed fluid actuation employed in soft robotics, I propose a thin and conformal actuator to be integrated with controllable adhesives. In section 10.1.4 of the NASA Technology Area (TA) Roadmap the need for hierarchical compliance, in controllable adhesives, to conform to irregular and uneven surfaces is well established. Soft robotics offers a highly promising solution to this problem due to inherent compliance, global load distribution, and conformal properties. However, soft robotic designs are often not regarded as suitable space technology candidates because they typically employ elastomeric materials, use pressure differentials for actuation, and do not guarantee precise movement or positioning. By using the hierarchical compliance and load distribution possible with soft robotics, for which the material and design methodologies will have to be validated for space application, my proposed soft robotic actuator should have the ability to substantially aid on-orbit gripping technologies. By developing an actuator for integration with controllable dry adhesives, I offer a solution to a direct technology pull from NASA in regard to surface conformity of controllable adhesives, while also addressing the more fundamental question of how to apply advances in the field of soft robotics to broader space applications. The core technology I propose is a thin fluid elastomer actuator optimized to aid controllable dry adhesives by generating preload, increasing load distribution, and most importantly, by conforming to a broad range of surface geometries. Fluidic elastomer actuators have a sealed internal cavity and can be used to generate motion by varying internal fluid pressure. The actuator can be directed to move with a specific motion by configuring the design and geometry of the internal chambers and the encapsulating elastomer layers. Thus, with a non-uniform stiffness, the actuator can be designed to extend, bend, or twist. A key property of elastomer actuators is that if in contact with a foreign object, actuator deformation patterns change due to the low stiffness of the actuator relative to the object. This property poses tremendous potential for controllable dry adhesives. By making a thin and highly conformal elastomer actuator pad, designed for use with such adhesives, it is possible to make an actuator that will conform to irregular surface geometries. My initial prototypes conform well to commonly found hardware and surfaces. Based on the property of elastomer actuators to conform to surrounding objects, their ability to generate preload with axial extension, and their distributed loading patterns, my hypothesis is that elastomeric actuators will enable dry adhesives to maintain adhesion on irregular surface geometries, such as those found on spacecraft. Specifically, I seek to use soft robotic optimization and modeling techniques to maximize and predict surface contact and adhesive force of the proposed actuator and integrated dry adhesives. As I develop prototypes, I will test this hypothesis in three ways. I will compare adhesive strength with and without an elastomer actuator, on flat surfaces, to ensure load distribution and preload properties are maintained. I will measure adhesive strength on a broad set of space-relevant irregular surfaces, such as MLI sheeting, surfaces with bolt heads, corners, and compound curves, and compare the adhesion to

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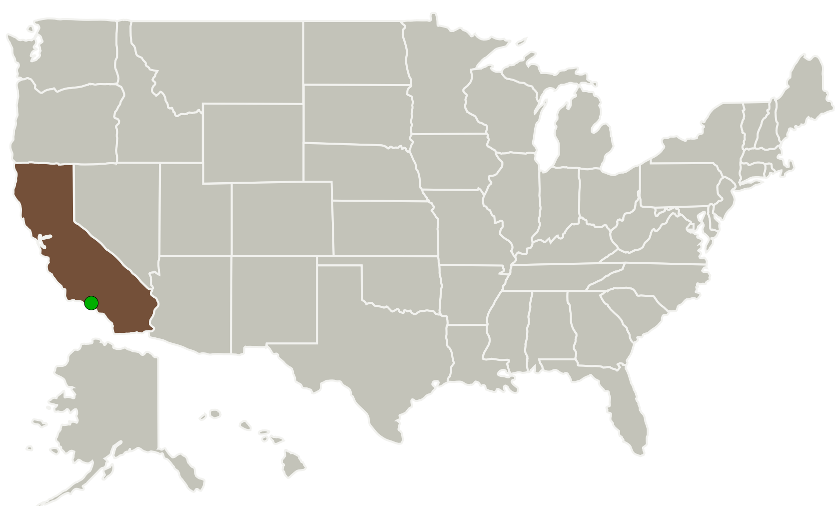
the baseline established for flat surfaces. Finally, I will show that this technology addresses complicated space tasks by grasping tumbling objects in two dimensions on air bearing platforms and in three dimensions with parabolic flight.

Anticipated Benefits

By developing an actuator for integration with controllable dry adhesives, this project offers a solution to a direct technology pull from NASA in regard to surface conformity of controllable adhesives, while also addressing the more fundamental question of how to apply advances in the field of soft robotics to broader space applications.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of California-San Diego(UCSD)	Lead Organization	Academia	La Jolla, California
Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of California-San Diego (UCSD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Michael Tolley

Co-Investigator:

Paul Glick

Primary U.S. Work Locations

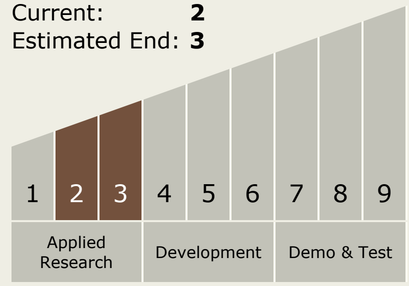
California

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX04 Robotic Systems
  - └ TX04.3 Manipulation
    - └ TX04.3.2 Grappling Technologies

Target Destinations

Earth, The Moon, Mars